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Effect of inter-repetition rest on ratings of perceived exertion during multiple sets of the power clean

Authors

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The purpose of this study was to examine the effects of inter-repetition rest (IRR) on ratings of perceived exertion (RPE) in the power clean exercise in a multiple set protocol using peak power as an indication of fatigue. Ten resistance-trained males participated in four testing sessions which consisted of determination of a one repetition maximum (1RM) in the power clean exercise (session 1) and performance of three sets of six repetitions at 80% of 1RM with 0 (P0), 20 (P20), or 40 s (P40) IRR (sessions 2–4). Fatigue during all three conditions was indicated by a significant decrease in power of 9.0% (P0), 3.0% (P20) and 2.1% (P40), respectively. Significant difference in the rate of power decrease in P40 indicates less fatigue in comparison to P0 and P20. P40 resulted in a significantly lower RPE compared to P0 and P20 (7.43 ± 0.34, 6.46 ± 0.47,and 5.30 ± 0.55, respectively). RPE increased significantly (p B 0.01) within each set (5.26 ± 0.37, 6.46 ± 0.44, and 7.46 ± 0.53; sets 1, 2, and 3, respectively). Significant difference in average RPE between the conditions indicates that RPE is not a determinant of intensity (% of 1RM) but the rate of fatigue (decreases in peak power). In addition, the fact that RPE increased between sets 1, 2 and 3 during all conditions support the same conclusion. The results demonstrate that increasing IRR in power clean training decreases the perception of effort and is inversely related to the rate of fatigue.

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Effect of inter-repetition rest on ratings of perceived exertion during multiple sets of the power clean

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Abstract The purpose of this study was to examine the effects of inter-repetition rest (IRR) on ratings of perceived exertion (RPE) in the power clean exercise in a multiple set protocol using peak power as an indication of fatigue. Ten resistance-trained males participated in four testing sessions which consisted of determination of a one repetition maximum (1RM) in the power clean exercise (session 1) and performance of three sets of six repetitions at 80% of 1RM with 0 (P0), 20 (P20), or 40 s (P40) IRR (sessions 2–4). Fatigue during all three conditions was indicated by a significant decrease in power of 9.0% (P0), 3.0% (P20) and 2.1% (P40), respectively. Significant difference in the rate of power decrease in P40 indicates less fatigue in comparison to P0 and P20. P40 resulted in a significantly lower RPE compared to P0 and P20 (7.43 ± 0.34, 6.46 ± 0.47, and 5.30 ± 0.55, respectively). RPE increased significantly (p B 0.01) within each set (5.26 ± 0.37, 6.46 ± 0.44, and 7.46 ± 0.53; sets 1, 2, and 3, respectively). Significant difference in average RPE between the conditions indicates that RPE is not a determinant of intensity (% of 1RM) but the rate of fatigue (decreases in peak power). In addition, the fact that RPE increased between sets 1, 2 and 3 during all conditions support the same conclusion. The results demonstrate that increasing IRR in power clean training decreases the perception of effort and is inversely related to the rate of fatigue.

Keywords Power · Strength · Training

Introduction

The original, Borg rating of perceived exercise (RPE) scale has frequently been used to monitor and assess aerobic exercise intensity in laboratory and clinical settings (Noble et al. 1983). The scale has been shown to correlate to variables such as heart rate (HR), workload (i.e., power output), muscle activity (i.e., EMG), and oxygen intake (VO_2) (Lagally et al. 2004; Noble et al. 1983; Skinner et al. 1973). More recently, in an effort to easily quantify resistance exercise, researchers have extended the RPE scale to resistance training. Kraemer et al. (1987) demonstrated RPE to be significantly correlated to blood lactate levels ($r = 0.84$) in bodybuilders and powerlifters. Suminski et al. (1997) found increases in blood lactate and RPE as the percentage of one repetition maximum (percentage of 1RM) increased during three sets of ten repetitions at 50 and 70% of 1RM, respectively. As indicated by the increases in blood lactate and RPE, these two studies indicate RPE may represent the level of fatigue during resistance exercise. Legally et al. (2002a) demonstrated performing one set of five repetitions at 90% of 1RM to be perceived harder than 1 set of 15 repetitions at 30% of 1RM. Furthermore, Lagally et al. (2002b) found RPE to increase as the percentage of 1RM increased (i.e., 4 repetitions at 90% of 1RM [6 repetitions at 60% of 1RM [12 repetitions at 30% of 1RM). Similarly, Day et al. (2004) demonstrated differences in RPE when performing exercises at varying intensities (i.e., 4–5 repetitions at 90% of 1RM [10 repetitions at 70% of 1RM [15 repetitions at 50% of 1RM).

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The aforementioned studies establish the concept that performing fewer repetitions at a higher percentage of 1RM is perceived harder than performing greater repetitions at a lower percentage of 1RM. However, these studies do not demonstrate a relationship between RPE and resistance exercise intensity (percentage of 1RM) due to the lack of control for differences in muscle contractions [i.e., submaximal (12 repetitions at 30% of 1RM) vs. maximal (4–5 repetitions at 90% of 1RM)]. It is known that submaximal and maximal muscle contractions elicit different metabolic and neural responses; therefore it is more likely in the previous investigations RPE may have been a representation of variables relating to muscular fatigue rather than percentage of 1RM. This notion can be supported, as Robertson et al. (2003) examined the effect of the number of repetitions performed with the percentage of 1RM held constant on RPE in men and women during submaximal upper- and lower-body exercises. The authors found a linear relationship between RPE and total weight lifted ($r = 0.79–0.91$) and blood lactate ($r = 0.87$) (Robertson et al. 2003). This further demonstrates the increases seen in RPE are most likely due to metabolic end products related to fatigue (i.e., hydrogen ions) and not necessarily the percentage of 1RM. Despite the lack of uniformity between submaximal and maximal efforts in the previous studies, RPE may have some application to reflect percentage of 1RM when it is taken during less fatigued states (i.e., midway through a set) rather than at a the completion of a repetition maximum. For example, Naclerio et al. (2011) examined RPE when there was a 10% decrease in average power (RPE_10%) during bench press repetitions to failure. Although the authors were unable to detect significant differences between similar percentage of 1RM ranges (i.e., 30–40% and [40–50%), they were able to detect differences between the high ([70–90%) and low (30–70%) percentage of 1RM ranges collectively (Naclerio et al. 2011). Therefore, RPE may have some application in the regulation of exercise training intensity during submaximal efforts on a global perspective due to its limitations for identifying small changes in percentage of 1RM.

A few studies have investigated the effect of inter-set rest during resistance training on RPE. Larson and Potteiger (1997) examined the effect of three different rest intervals on exercise performance during multiple squatting bouts to fatigue. The rest interval conditions included: (1) a post-exercise heart rate of 60% age-predicted maxi- mum, (2) a timed 3 min, and (3) a work to rest ratio of 1:3. The authors found no differences in repetitions to failure, blood lactate concentrations, and RPE between the three inter-set rest conditions; however, there were significant increases in post-exercise blood lactate concentrations and pre-set RPE values within each condition (Larson and Potteiger 1997). Furthermore, Pincivero et al. (1999) found increases in RPE over multiple sets, with no differences between 40- and 160-s inter-set rest during knee extension exercise. However, the 40-s group demonstrated significant decreases in peak torque, total work, and average power (Pincivero et al. 1999). Similarly, Woods et al. (2004) found no differences in the perceived exertion response between inter-set rest of 1, 2, or 3 min during three sets of ten repetitions of knee extension exercise. These studies demonstrate that 3 min inter-set rest may not be sufficient to mediate optimal muscle recovery during maximal, fatiguing contractions lasting greater than 10 repetitions.

Singh et al. (2007) found the CR-10 scale to be effective at monitoring perceived effort during different types of resistance exercise. The authors demonstrated strength- and hypertrophy-oriented protocols elicited significantly greater average and session RPE than a power-oriented protocol (Singh et al. 2007). This may suggest higher power outputs will be associated with a lower RPE and a lower perceived exertion might be desired when training for muscular power. The ability to generate maximum muscular force, and ultimately power, is dependent on the level of muscular fatigue (Pincivero et al. 1999). Therefore, RPE may have practical application during power training due to its representation of muscular fatigue (Kraemer et al. 1987; Suminski et al. 1997). As previously discussed, Naclerio et al. (2011) examined RPE, training intensity (percentage of 1RM), and power output during submaximal bench press repetitions to failure. Unlike previous studies, the authors monitored power output while collecting RPE at the completion of each repetition and completion of each set. This methodology allowed RPE within the set to reflect changes in power output. The authors found significant decreases in power output and significant increases in RPE across repetitions (Naclerio et al. 2011). To date, no study has examined the relationship between RPE and power output during weightlifting exercises (i.e. power clean).

Recently, IRR have become of interest to individuals concerned with the development of muscular power. This method of training employs taking brief periods of rest (15–45 s) between repetitions (Haff et al. 2003; Lawton et al. 2006), and two studies have examined their effect on resistance training performance. Haff et al. (2003) and Lawton et al. (2006) demonstrated IRR to attenuate fatigue, which allowed for the maintenance of power, velocity, and displacement during a single set exercise protocol. Although neither study analyzed RPE during their investigation, it can be speculated that IRR may manifest changes to RPE due to attenuation of fatigue. If fatigue decreases power output and is an unwanted byproduct during power training, based on the previous findings (Singh et al. 2007; Haff et al. 2003; Lawton et al. 2006), IRR may be a rational methodology to attenuate increases in RPE when training for power. Interestingly, the effects of IRR on RPE are still unknown, but there seems to be an association between RPE, fatigue, and power output. Therefore, the purpose of this investigation was to examine the effect of IRR on RPE in a multiple set exercise protocol. In addition, to examine the relationship between RPE and muscular fatigue as indicated through decreases in power output in the power clean exercise.

Methodology

Experimental design

All subjects participated in four testing sessions over a period of 2 weeks with 72 h given between each session. Session 1 consisted of documentation, determination of a one repetition maximum (1RM) in the power clean, and familiarization to the CR-10 RPE scale. In a randomized order, during sessions 2–4 subjects performed three sets of six repetitions at 80% of 1RM with 0 (P0), 20 (P20), or 40 s (P40) IRR with 3 min rest given between sets. Power was collected for each repetition and peak values were analyzed as described by Cormie et al. (2007). RPE was obtained after the completion of the last repetition in each set.

Subjects

Ten male, recreational weightlifters participated in this study (age = 23.6 ± 0.37 years; body mass = 80.36 ± 0.90 kg; height = 1.77 ± 0.005 meters; power clean 1RM/body mass = 1.39 ± 0.01; mean ± standard error). Subjects had at least 4 years of weight training, 1 year of Olympic weightlifting experience, and were required to display proper technique of the power clean exercise for participation in this study. During the time of the study all sub- jects were training for strength and power and were not currently competing in any outside sports. In addition, subjects were aware of IRR but had not undertaken this type of training in their current training program. Subjects were asked to refrain from strenuous activities and main- tain normal dietary habits between each session. All sub- jects read and signed a written informed consent approved by the Institutional Review Board at Appalachian State University.

Preliminary testing: session 1

All subjects reported to the Neuromuscular and Biomechanics Laboratory at Appalachian State University for session 1 after refraining from strenuous exercise for a minimum of 72 h. During this time subjects were measured for height and weight, and a 1RM in the power clean exercise was determined. Power clean 1RM testing was performed as described by Winchester et al. (2005). Briefly, subjects underwent a series of warm-up sets consisting of five repetitions at 50% of pre-determined 1RM, three repetitions at 70% of pre-determined 1RM, and one repetition at 90% of pre-determined 1RM. The pre-determined 1RM was calculated from the subjects' current resistance training program. Upon completion of the warm-up sets, subjects underwent several maximal lifts until a 1RM is achieved. All subjects obtained a 1RM greater than their pre-determined 1RM. Proper technique of the power clean was assessed as discussed previously (Baumann et al. 1988; Burdett 1982; Canavan et al. 1996; Frolov et al. 1979; Garhammer 1984; Isaka et al. 1996; Winchester et al. 2005, 2009). Familiarization to the CR-10 RPE scale took place during this time using low and high anchoring procedures previously described (Robertson et al. 2004; Woods et al. 2004).

Protocol testing: sessions 2–4

In a randomized order, each subject completed the following three testing sessions. Subjects were asked to refrain from strenuous exercise between testing sessions and to maintain normal dietary habits. During sessions 2–4 subjects performed three sets of six repetitions at 80% of 1RM with 0, 20, or 40 s of IRR, respectively. Previous literature has shown 80% of 1RM be the optimal load for peak and average power in the power clean exercise (Cormie et al. 2007). Peak power was measured for each repetition and averaged for each set of each protocol. RPE was obtained at the completion of each set and a 3-min rest period was given between sets. All testing sessions (sessions 1–4) were separated by a minimum of 72 h to allow for complete recovery.

Power output determination

All kinetic and kinematic data was collected and analyzed with LabVIEW (National Instruments, Version 7.1) software as described by Cormie et al. (2007). Testing was conducted with subjects standing on a force plate (AMTI, BP60011200; Watertown, MA) with two linear position transducers (2-LPT) (Celesco PT5A-15; Chatsworth, CA) attached to the right side of the barbell. Analog signals from the force plate and 2-LPT were collected at 1,000 Hz using a BNC-2010 interface box with an analog-to-digital card (National Instruments PCI-6014; Austin, TX). The voltage outputs from the force plate and 2-LPT were converted to force (*N*) and displacement (*m*), respectively. Peak force was determined from the force–time curve generated from the force plate; whereas peak velocity was determined from the velocity–time curve generated by using the displacement–time data generated by the 2-LPT's. Power output was calculated by the multiplication of force–time and velocity–time curves. All values were obtained during the second pull of the power clean. This method has displayed intra-class correlation coefficients (ICC) above the minimum acceptable criterion of 0.70 and were significant at an alpha level of *p* B 0.05 (ICC = 0.98) (Cormie et al. 2007).

Ratings of perceived exertion

Familiarization to the CR-10 RPE scale took place during session 1 using low and high anchoring procedures as previously described (Robertson et al. 2004; Woods et al. 2004). During sessions 2–4, RPE was obtained after the completion of the last repetition in each set using a modified CR-10 RPE scale (Day et al. 2004). Subjects were asked to rate the overall perceived exertion for the completed exercise set. This scale has been established as a valid instrument to evaluate perceived exertion during resistance exercise (Day et al. 2004; Dishman et al. 1987; Gearhart et al. 2001; Lagally et al. 2002b; Pierce et al. 1993; Suminski et al. 1997). The scale consists of numbers 0–10, with each number corresponding to a qualitative feeling of effort. A rating of 0 is associated with no effort whereas a rating of 10 is considered to be maximal effort and associated with the most strenuous exercise ever performed (Day et al. 2004).

Statistical analysis

A repeated measure one-way ANOVA was used to determine differences between RPE and IRR. Significance was set at *p* B 0.05 for all analysis. A 3 9 3 9 6 (protocol 9 set 9 repetitions) repeated measures ANOVA was used to determine differences in the average percent change in power output between IRR protocols. When significant main effects were determined, a Bonferoni post hoc was used to determine statistical significance. All statistical analysis was performed using SPSS version 17.0 (SPSS Inc., Chicago, IL, USA).

Results

Average RPE for each protocol is presented in Fig. 1. A significant main effect was found for protocol ($F_{2,18}$ = 20.25, *p* B 0.001). Average RPE for P0 and P20 were significantly different from P40 (7.43 ± 0.34, 6.46 ± 0.47, and 5.30 ± 0.55, respectively). The average RPE for each set is presented in Fig. 2. A significant main effect was found for set ($F_{2,18}$ = 30.58, *p* B 0.001). Average RPE for set 2 was significantly different from set 1 (*p* B 0.01).

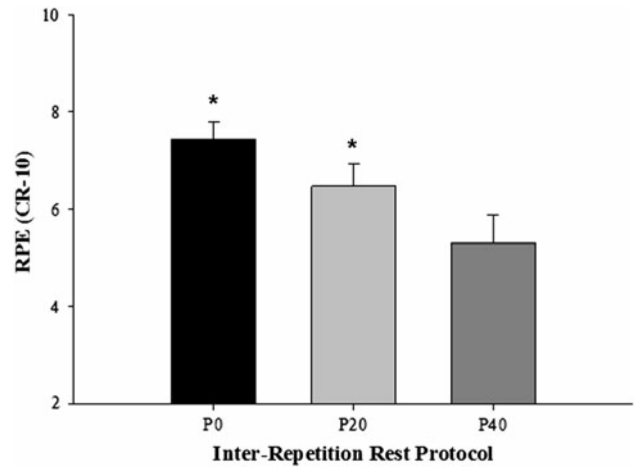

Fig. 1 Average RPE for each IRR protocol. P0 = 0 s IRR, P20 = 20 s IRR, P40 = 40 s IRR. *Significantly different from P40 (*p* B 0.05)

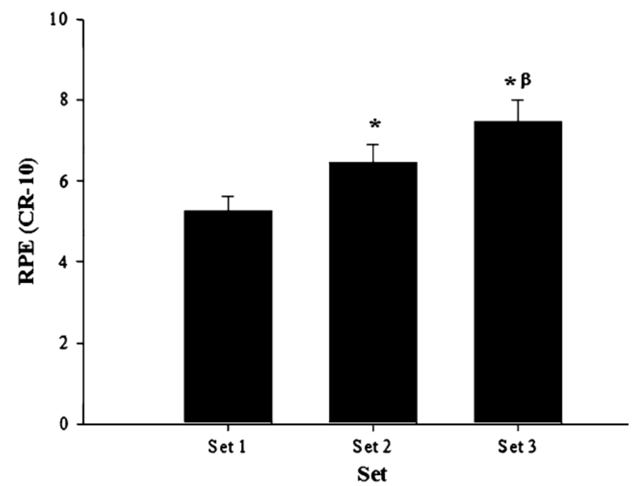

Fig. 2 Average RPE for each set. *Significantly different from set 1 (*p* B 0.05). [b]Significantly different from set 2 (*p* B 0.05)

Average RPE for set 3 was significantly different from sets 1 and 2 (*p* B 0.01). In addition, for each exercise protocol RPE significantly (*p* B 0.05) increased with each set (Fig. 3).

Differences in the rate of decrease in power were found between protocols. The average peak power for each protocol decreased by 9.0, 3.0, and 2.1% (P0, P20, and P40, respectively). Average percent change in peak power across each set is presented in Table 1. P0 demonstrated significant decreases in peak power across each set when compared to the IRR protocols (*p* \ 0.05). Average percent change in peak power across each repetition is shown in Table 2. P0 demonstrated significant decreases in peak power across each set when compared to the IRR protocols (*p* \ 0.05).

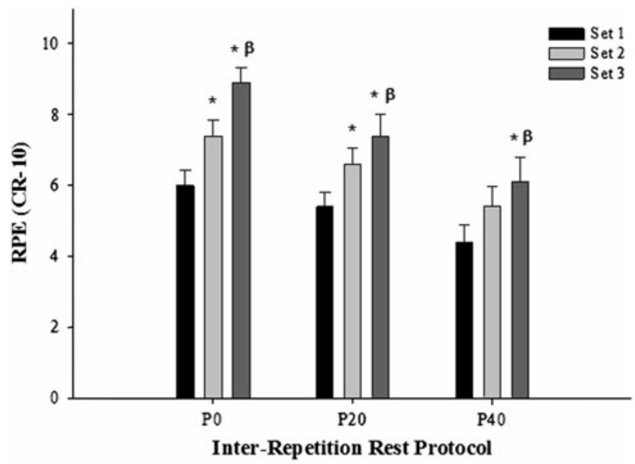

Fig. 3 Average RPE for each set of each IRR protocol. P0 = 0 s IRR. P20 = 20 s IRR. P40 = 40 s IRR. *Significantly different from set 1 (*p* Β 0.05). [b]Significantly different from set 2 (*p* Β 0.05)

Table 1 Average percent change in peak power across multiple sets

	Set		
	1	2	3
P0	-7.55 ± 1.23	-8.65 ± 1.08	-10.82 ± 1.13
P20	-3.37 ± 1.00*	-4.38 ± 1.24*	-1.46 ± 1.09*
P40	-2.52 ± 1.01*	-2.32 ± 1.21*	-1.68 ± 1.14*

* Significantly diffrent from P0 (*p* \ 0.05)

Discussion

The primary finding in this investigation is that RPE represents the level of fatigue, in terms of power output, during power clean training and not necessarily the intensity of the protocol, in terms of percentage of 1RM. As the subjects completed subsequent sets in each protocol, power significantly decreased with an associated increase in RPE. This is similar to the findings by Naclerio et al. (2011) that showed high RPE's with decreasing power output in the bench press irrespective of the level of intensity (percent- age of 1RM) of the condition (from 30–90% of 1RM). Thus, RPE may be a good indication as to the level of fatigue induced by resistance exercise but not necessarily the intensity (percentage of 1RM) of the protocol. In addition, IRR periods can attenuate the increases in RPE and decreases in power output. This may be a desirable result as Kaneko et al. (1983) showed that high power outputs within each repetition resulted in the greatest power adaptations with exercise.

Several investigations have examined the effect of a multiple set protocol on RPE and found significant increases in RPE across repetitions with each subsequent set (Larson and Potteiger 1997; Pincivero et al. 1999; Woods et al. 2004). Similarly, the current investigation found significant differences (*p* Β 0.01) in RPE between sets as a whole (all protocols averaged) and within individual protocols (Figs. 2, 3). Furthermore, the results demonstrate IRR periods greater than 20 s within a multiple set exercise protocol can decrease the perception of effort in the power clean exercise. This may be explained by IRR allowing partial recovery from exercise, thereby decreasing the perception of effort. It is thought phosphocreatine (PCr) depletion may act to increase RPE (Lagally et al. 2002b), and previous research has demonstrated a strong relationship between decreases in force production and associated decreases in PCr (*r* = 0.71–0.86; *p* Β 0.05) during high-intensity exercise in skeletal muscle (Bogdanis et al. 1995, 1996; Miller et al. 1987). It can be speculated in the current investigation that the decreases in power output seen were due to decreases in PCr levels in the working muscle. Therefore, a possible mechanism may include that decreases in PCr lead to both the subsequent increases in RPE and decreases in power output. However, since PCr was not measured in this investigation we cannot conclude this definitively.

Despite this limitation, this assumption may be warranted due to coincidental decreases in peak power and an increase in RPE. Numerous researchers have demonstrated increases in RPE to be associated with increases in blood lactate (Kraemer et al. 1987; Suminski et al. 1997). Increased lactate concentrations are due to a reliance on anaerobic glycolysis (di Prampero and Ferretti 1999) and facilitates the reduction of intracellular hydrogen ions during maximal exercise (Myers and Ashley 1997). However, excess hydrogen ion concentrations in skeletal muscle can lead to an acidic environment which stimulates nerve endings in the muscle cell, increasing the perception of

Table 2 Average percent change in peak power across six repetitions in the power clean exercise

	Repetition					
	1	2	3	4	5	6
P0	0.00 ± 0.00	-2.77 ± 0.59	-6.87 ± 0.54	-9.64 ± 0.53	-10.13 ± 0.65	-15.65 ± 0.60
P20	0.00 ± 0.00	-2.04 ± 0.65	-1.38 ± 0.65*	-2.60 ± 0.69*	-3.85 ± 0.55*	-5.51 ± 0.69*
P40	0.00 ± 0.00	-0.49 ± 0.61	-1.84 ± 0.73*	-2.31 ± 0.65*	-2.94 ± 0.62*	-3.31 ± 0.65*

* Significantly diffrent from P0 (*p* \ 0.05)

effort (Pandolf 1978; Stamford and Noble 1974). Therefore, increasing the perception of effort during resistance training may be associated with an increased reliance on anaerobic glycolysis and the inability to buffer hydrogen ions rather than immediate energetic pathways such as the ATP-PC system. Since the development of muscular power is highly dependent on the level of muscular fatigue, perceived exertion could be used as an intrinsic regulator of muscular fatigue with regards to power training.

Based on the data presented in this study, RPE appears to represent the level of fatigue during resistance exercise. This relationship could also be explained by neural factors. Hasson et al. (1989) found a significant, inverse relationship (r^2 = -0.92) between RPE and mean power frequency (MPF) during sustained-isometric contractions. A decrease in MPF during exercise is thought to be an indicator of fatigue as there is a reduction in muscle fiber action potential conduction velocity. Furthermore, Stewart et al. (2011) demonstrated a positive relationship between muscle fiber conduction velocity and power output ($r = 0.54$, $p < 0.01$) and torque ($r = 0.727$, $p < 0.01$) during a 30-second Wingate cycle test. Therefore, it could be speculated in the current investigation that decreases in muscle fiber conduction velocity may also be responsible for the decreases in power output seen. In addition, the use of IRR periods may attenuate the decreases to conduction velocity; thereby attenuating increases in RPE and decreases in power. However, these precise variables were not measured in the current investigation and should be addressed in future research.

Conclusion

In summary, this study examined the association between RPE, fatigue, and power output during resistance exercise. This was the first study to examine the effect of IRR on RPE during a multiple set exercise protocol oriented at the production of maximal power output. The results demonstrate that increases to RPE were attenuated through the use of IRR and increases in RPE were coincidental with decreases in power output. These two results have direct implications when training for muscular power. First, it appears that RPE represents the level of fatigue, in terms of power output, during a multiple set exercise protocol in the power clean exercise, rather than the percentage of 1RM. Second, since training at the highest power outputs within each repetition results in the greatest power adaptation with exercise training (Kaneko et al. 1983), perceived exertion may be utilized as a valuable tool when training for muscular power. Future research should examine the longitudinal training adaptations while utilizing RPE during periods of muscular power development.

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Conflict of interest The authors declare that they have no conflicts of interest.

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